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(54) Manufacturing bar

(57) In a method for manufacturing a torsion bar of a power steering device, by the cold drawing of round-bar steel having a diameter larger than a diameter of finished connecting portions A, B of the torsion bar, a twist portion M having a predetermined length and diameter is shaped. The surface of the twist portion is smoothly processed. Through work hardening, the hardness of the twist portion increases, thereby simplifying the final thermal refining process. As a result, a torsion bar with a special configuration, a desired surface roughness, and a desired hardness can be processed through a reduced number of process steps.

FIG. 1

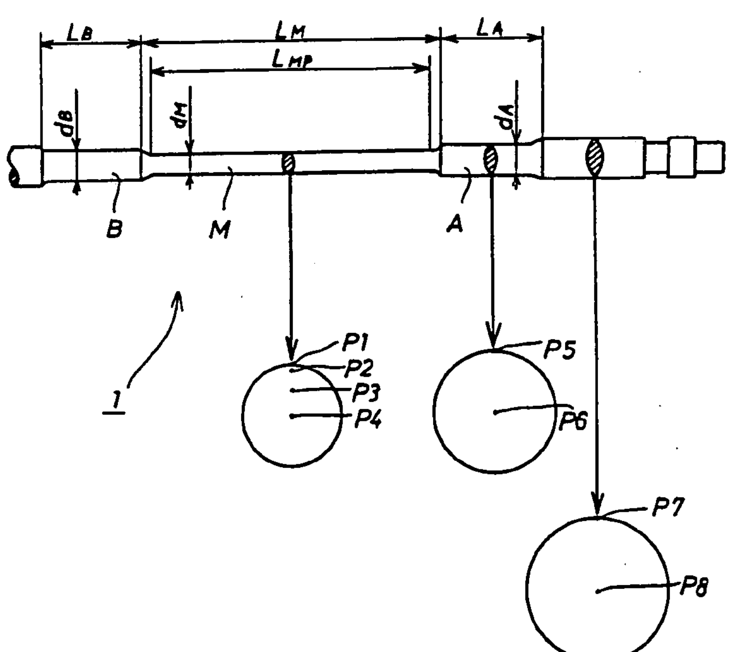




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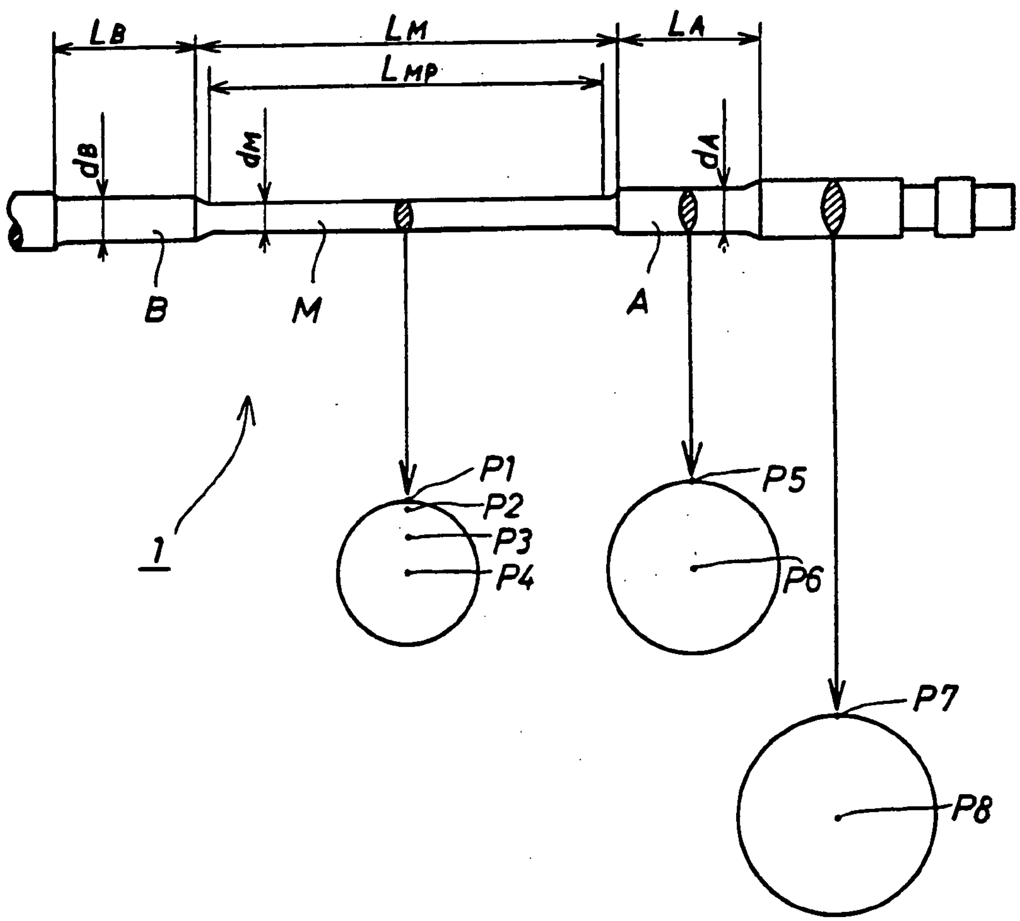
FIG. 1



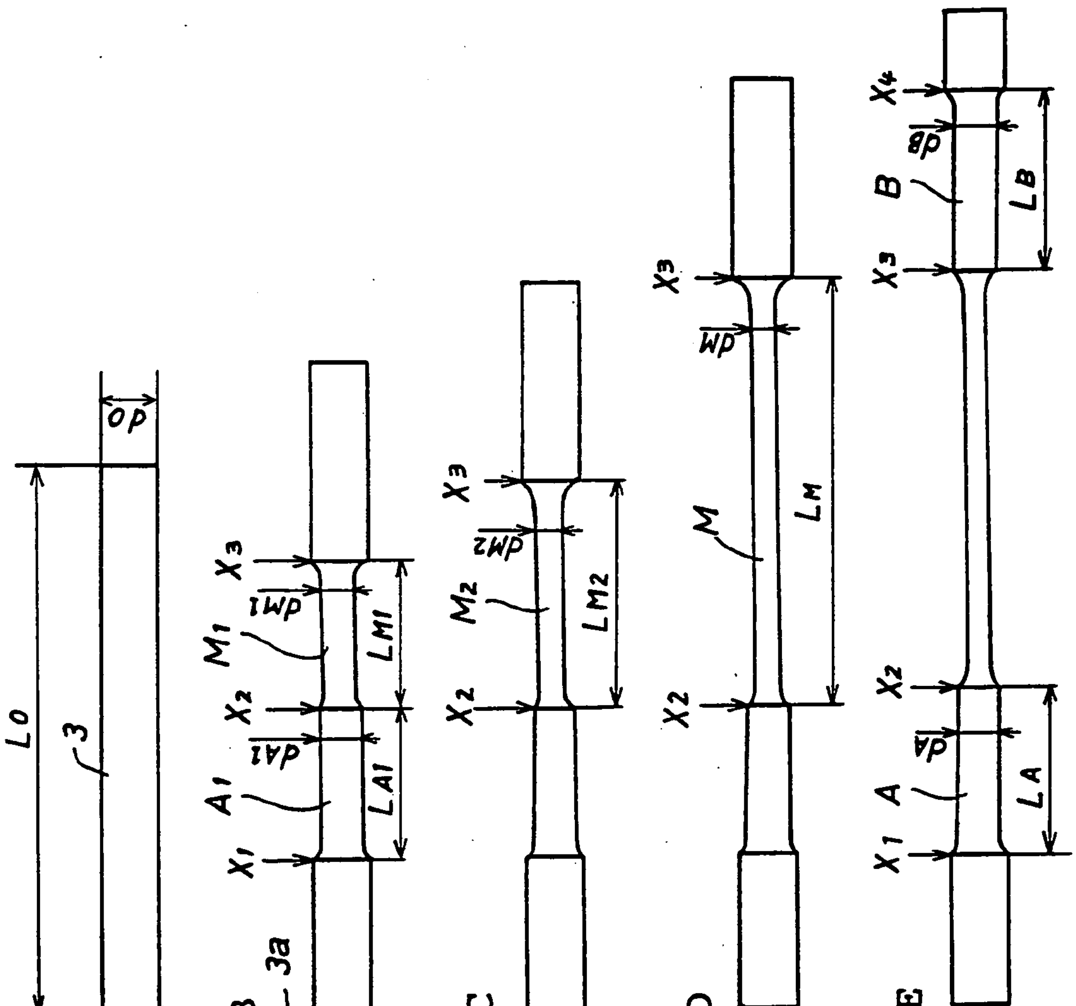



FIG. 2A

FIG. 2B

FIG. 2C

FIG. 2D

FIG. 2E

# A METHOD FOR MANUFACTURING A TORSION BAR OF A POWER STEERING DEVICE

## BACKGROUND OF THE INVENTION

This invention relates to a method for manufacturing a torsion bar of a power steering device from round-bar steel.

Conventionally, in an automotive vehicle power steering device, a torsion bar is interposed between an input shaft and an output shaft. A valve sleeve is slidably inserted onto the outer periphery of the input shaft, thereby forming a rotary valve. The torsion bar is a component that governs the characteristics of the power steering device and should have sufficient strength and durability.

A twist portion of the torsion bar should have a given hardness and surface roughness to give sufficient strength and durability to the power steering device. The torsion bar that is thin in its middle portion and thick in its both ends is integrally manufactured as follows.

First, a given range of round-bar steel is cut to form a twisted middle portion and thermally processed to have a given hardness. Subsequently, the cut range of the round-bar steel is polished to have a given surface roughness.

The above related-art manufacturing method involves a number of process steps, thus increasing cost for manufacturing the torsion bar.

If the polishing step, for example, is eliminated to decrease the number of process steps, precision in cutting step should be increased, resulting in increased number of process steps for cutting the given range of the round-bar

steel precisely to obtain the given surface roughness.

If round-bar steel with less hardness is used so as to facilitate the cutting step, the torsion bar lacks in its hardness. Therefore, the thermal processing step becomes intricate.

## SUMMARY OF THE INVENTION

An object of the invention is to provide a method for manufacturing a torsion bar of a power steering device that comprises a reduced number of process steps for manufacturing a durable torsion bar, and comprises a simplified thermally refining step.

To attain this and other objects, the invention provides a method for manufacturing a torsion bar of a power steering device from round-bar steel. The torsion bar connects an input shaft and an output shaft of the power steering device. The torsion bar comprises a twist portion with small diameter and with given surface roughness corresponding to desired durability of the power steering device, and connecting portions with large diameter at both ends of the twist portion. The round-bar steel prior to processing has a diameter larger than a finished diameter of the connecting portions of the torsion bar. Processed dimensions of the round-bar steel are determined based on an amount of the round-bar steel required for the twist portion, which is determined by a finished length and a finished diameter of the twist portion and based on the diameter of the round-bar steel prior to processing. A cold drawing step is made on the processed range of the round-bar steel to obtain the

finished diameter of the twist portion.

## BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is an explanatory view showing a configuration and hardness measurement portions of a swaged torsion bar.

Figs. 2A through 2E are explanatory views showing states of a torsion bar in process.

## DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

As shown in Fig. 1, a torsion bar 1 manufactured in this embodiment comprises a twist portion M having a diameter dM of 5.3mm and a length LM of 69.5mm. A length LMP of a parallel portion is 62.2mm. The torsion bar 1 also comprises an input-shaft connecting portion A having a diameter dA of 8.58mm and a length LA of 38.0mm, and an output-shaft connecting portion B having a diameter dB of 9.51mm and a length LB of 23.0mm. The torsion bar 1 is made by swaging round-bar steel consisting of structural carbon steel SCM435 (according to Japanese Industrial Standard), special alloy steel (steel not thermally refined), or spring steel SUP9 (according to Japanese Industrial Standard).

As shown in Fig. 2A, a round-bar steel 3 has a diameter d0 of 9.7mm and a length L0 of 201.5mm. The diameter d0 and the length L0 are determined based on finished dimensions of the torsion bar 1 and a dimension for a chuck of a swaging machine for holding the round-bar steel 3.

The round-bar steel 3 is set in the swaging machine and

processed through four-step cold drawing as shown in Figs. 2B through 2E.

The swaging machine comprises dies of tungsten carbide (WC) alloy, a kind of tool steel, and an adjusting member for adjusting distance between the dies. By operating the adjusting member according to processing program and changing the distance between the dies, cold drawing is continuously carried out, thereby forming various diameters of the torsion bar 1.

Four-step processing will now be explained.

FIRST PROCESS STEP AS SHOWN IN FIG. 2B

First, the distance between the dies of the swaging machine is adjusted to a processed diameter dA1 of 8.8mm. A first position X1, which is a given distance from a chucking end 3a of the round-bar steel 3 and corresponds to a start position of the input-shaft connecting portion A, is inserted into the swaging machine such that the first position X1 is aligned with the dies. Subsequently, the round-bar steel 3 is pulled toward the left in the figure at a given speed until a second position X2 reaches the dies. A first processed portion A1 of the input-shaft connecting portion A is thus shaped and has a diameter dA1 of 8.8mm and a length LA1 of 35.5mm. After the distance between the dies is adjusted to a processed diameter dM1 of 8.3mm, the round-bar steel 3 is further pulled from the dies toward the left in the figure until a third position X3 reaches the dies. A first processed portion M1 of the twist portion M is thus shaped and has a diameter dM1 of 8.3mm and a length LM1 of

30.5mm.

SECOND PROCESS STEP AS SHOWN IN FIG. 2C

The second position X2 is aligned with the dies. The distance between the dies is adjusted to a processed diameter dM2 of 6.8mm. The round-bar steel 3 is pulled toward the left in the figure until the third position X3 reaches the dies. A second processed portion M2 of the twist portion M is thus shaped and has a diameter dM2 of 6.8mm and a length LM2 of 44.2mm.

THIRD PROCESS STEP AS SHOWN IN FIG. 2D

Subsequently, the distance between the dies is adjusted to the diameter dM of 5.3mm. The round-bar steel 3 is then pulled from or pushed into the dies repeatedly. The length between the second position X2 and the third position X3 is thus further swaged. The twist portion M having the diameter dM of 5.3mm and the length LM of 69.5mm is finished.

FOURTH PROCESS STEP AS SHOWN IN FIG. 2E

The second position X2 of the round-bar steel 3 is aligned with the dies of the swaging machine. The distance between the dies is adjusted to the diameter dA of 8.58mm. The round-bar steel 3 is pushed into the dies until the first position X1 reaches the dies. The input-shaft connecting portion A is thus finished and has the diameter dA of 8.58mm and the length LA of 38.0mm. Subsequently, the third position X3 of the round-bar steel 3 is aligned with the dies. The distance between the dies is adjusted to the diameter dB of 9.51mm. The round-bar steel 3 is pulled toward the left in the figure until a fourth position X4

reaches the dies. The output-shaft connecting portion B is thus finished and has the diameter of 9.51mm and the length LB of 23.0mm.

In the embodiment, the above four process steps were carried out for a given time period of one minute and forty-four seconds according to a predetermined processing program.

Hardness of the twist portion M and the input-shaft connecting portion A of the torsion bar 1 manufactured as aforementioned was measured. Hardness of not-swaged portion of the torsion bar 1 (hereinafter referred to as the blank hardness) was also measured.

The Vickers hardness test was performed on a surface P1 of the twist portion M, a position P2 0.05mm inside the position P1, a position P3 at a quarter of the diameter dM, a center P4 of the diameter dM of the twist portion M, a surface P5 of the input-shaft connecting portion A, and a center P6 of the diameter dA of the input-shaft connecting portion A. To obtain the blank hardness, the Vickers hardness test was also performed on a surface P7 of a not-swaged portion, and on a center P8 of a diameter of the not-swaged portion. No measurement was made on some portions of test pieces. Results of the Vickers hardness test are shown in Table 1.

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TABLE 1

| NO. | ROUND-BAR STEEL | | MEASURED HARDNESS (UNIT:HV) AFTER SWAGING | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | STEEL TYPE | HARDNESS | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 |
| 1 | SCM435 | HRC12 | 290 | 295 | 265 | 260 | 234 | 228 | 196 | 195 |
| 2 | SCM435 | HRC15 | 307 | 315 | 297 | 297 | 252 | 249 | 219 | 213 |
| 3 | SCM435 | HRC29 | 326 | 350 | 339 | 340 | 294 | 302 | 288 | 288 |
| 4 | SCM435 | HRC12 | - | - | 258 | 256 | 215 | 228 | 199 | 193 |
| 5 | SPECIAL ALLOY STEEL | HRC25 | - | - | 294 | 297 | 266 | 266 | 260 | 264 |
| 6 | SUP9 | HRC30 | - | - | 351 | 354 | 292 | 299 | - | - |

In Table 1, as test pieces No.1 and 4, the structural carbon steel SCM435 with a hardness of Rockwell hardness HRC12 was not thermally refined. The structural carbon steels SCM435 as test pieces No.2 and 3 were thermally refined before swaging to have Rockwell hardness HRC15 and HRC29, respectively. A test piece No.5 was the special alloy steel not thermally refined. A test piece No.6 was the spring steel SUP9.

At each twist portion M of the test pieces No.1 through 6, much increase in hardness was found. Especially, the hardness of the test piece No.6 rose to the Vickers hardness of HV354 at the center P4 of the twist portion M. The Vickers hardness of HV354 equals the Rockwell hardness of HRC37. The hardness of the test piece No.3 rose to the Vickers hardness of HV350, about HRC37 at the position P2 of the twist portion M.

The test pieces No.3 and 6 satisfy the hardness required for the torsion bar 1 of the power steering device. The other test pieces No.1, 2, 4 and 5, if further thermally refined after swaging, can have sufficient hardness. If usage conditions of the torsion bar 1 are limited, the thermal refining can be omitted.

Through swaging, the hardness of the test pieces No.3, 5 and 6 with the hardness more than HRC25 can be increased by HRC5 through HRC7.

Through swaging, the hardness of the test piece No.2 was increased to HRC31, exchanged into the Rockwell hardness. The rate of increase of the test piece No.2 was the largest

of all the test pieces. Since the test piece No.2 was thermally refined, the test piece No.2 was soft enough to process easily.

Three test pieces No.6 of SUP9 were used, and the surface roughness of the twist portion M thereof was measured. Maximum surface roughness Rmax was between 1.4 m and 2.2 m and average surface roughness Ra was 0.2 m. The test pieces No.6 has the surface roughness sufficient for the torsion bar 1.

As aforementioned, in the embodiment, the round-bar steel not thermally refined has the surface roughness sufficient for the torsion bar 1, and can have the sufficient hardness if a little thermally refined. The test pieces No.3 and 6, which has the hardness more than HRC29, has sufficient surface roughness and hardness. As a result, without polishing the round-bar steel, and by thermally refining the round-bar steel in a simple way or without thermally refining the round-bar steel, the torsion bar 1 with sufficient physical properties can be manufactured. The number of process steps for manufacturing the torsion bar can thus be reduced.

Swaging is an easier operation than cutting. In the embodiment, the number of the process steps is decreased through swaging.

The related-art method comprises a cutting process, a thermal refining process and polishing process. These processes involve attachment and detachment of material steel. As compared with such intricate related art, the

embodiment has less number of process steps. Especially, the test pieces No.3 and 6 can be finished through one process.

Work hardening can be expected during the swaging process in the embodiment. Therefore, the material steel soft enough to swage easily can be used.

Since the torsion bar can be manufactured without losing any of the material steel, yield is thus enhanced.

In the embodiment, the structural carbon steel SCM435 not thermally refined, the structural carbon steels SCM435 thermally refined, the special alloy steel not thermally refined, and the spring steel SUP9 are used as the material steels. However, any other type of steel can be used.

From the above description of a preferred embodiment of the invention, those skilled in the art will perceive improvements, changes, and modifications. Such improvements, changes and modifications within the skill of the art are intended to be covered by the appended claims.

For example, any cold drawing process involving work hardening can be applied instead of the swaging process.

The diameter of the round-bar steel, if the diameter exceeds the largest diameter of the finished torsion bar and accords with the capacity of the swaging machine, can be various.

WHAT IS CLAIMED IS:

1. A method of manufacturing a torsion bar of a power steering device, comprising the steps of:

performing a first cold drawing process on a steel bar to form first and second sections on the steel bar;

performing a second cold drawing process on the second section on the steel bar;

performing a third cold drawing process on the second section on the steel bar; and

performing a fourth cold drawing process on the second section on the steel bar and on a third section on the steel bar that has not previously been cold drawn.

2. The method of manufacture of claim 1, in which, after the first through fourth cold drawing processes are performed, a diameter of the second section is less than a diameter of the first and third sections.

3. The method of manufacture of claim 1, in which the first through fourth cold drawing processes comprise the step of swaging the steel bar.

4. The method of manufacture of claim 1, in which the second section comprises a twist section of the torsion bar.

5. The method of manufacture of claim 1, in which the process of cold drawing the steel bar hardens the steel bar.

6. The method of manufacture of claim 1, in which

a material of the steel bar is chosen from the group of materials consisting of structural carbon steel not thermally refined, structural carbon steel thermally refined, special alloy steel not thermally refined, and spring steel.

7. The method of manufacture of claim 1, further comprising the step of thermally refining the steel bar after the fourth cold drawing process is performed to harden the cold processed steel bar.

8. The method of manufacture of claim 1, further comprising the step of predetermining a length and diameter of the steel bar before the step of performing the first cold drawing process based on desired lengths and diameters of the first, second, and third sections of the cold processed steel bar.

9. A method of manufacturing a torsion bar of a power steering device, comprising the steps of:

performing a first cold drawing process on a steel bar to form first and second sections on the steel bar, where a diameter of the first section is less than a diameter of the steel bar before the first cold drawing process is formed and a diameter of the second section is less than the diameter of the first section;

performing a second cold drawing process on the second section on the steel bar such that the diameter of the second section is reduced;

performing a third cold drawing process on the

second section on the steel bar such that the diameter of the second section is further reduced; and

performing a fourth cold drawing process on the second section on the steel bar such that the diameter of the second section is further reduced and on a third section on the steel bar that has not previously been cold drawn, where the second section is formed on the bar between the first and third sections.

10. The method of manufacture of claim 9, in which, after the first through fourth cold drawing processes are performed, the diameter of the second section is less than the diameter of the first section and a diameter of the third section.

11. The method of manufacture of claim 9, in which the first through fourth cold drawing processes comprise the step of swaging the steel bar.

12. The method of manufacture of claim 9, in which the process of cold drawing the steel bar hardens the steel bar.

13. The method of manufacture of claim 9, in which a material of the steel bar is chosen from the group of materials consisting of structural carbon steel not thermally refined, structural carbon steel thermally refined, special alloy steel not thermally refined, and spring steel.

14. The method of manufacture of claim 9, further comprising the step of thermally refining the steel bar after

the fourth cold drawing process is performed to harden the cold processed steel bar.

15. The method of manufacture of claim 9, further comprising the step of predetermining a length and diameter of the steel bar before the step of performing the first cold drawing process based on a desired lengths and diameters of the first, second, and third sections of the cold processed steel bar.

16. A method of manufacturing a torsion bar of a power steering device, comprising the steps of:

predetermining a length and thickness of a steel bar;

beginning a first swaging process with a swaging machine on a steel bar to form a first section having a first diameter on the steel bar;

adjusting a set of dies of the swaging machine for a first time;

continuing the first swaging process on the steel bar to form a second section having a second diameter on the steel bar, where the second diameter is less than the first diameter;

performing a second swaging process on the second section on the steel bar such that the second diameter is reduced;

performing a third swaging process on the second section on the steel bar such that the second diameter

is further reduced;

beginning a fourth cold drawing process on the second section on the steel bar such that the second diameter is further reduced;

adjusting the set of dies of the swaging machine for a second time; and

continuing the fourth swaging process on the steel bar to form a third section having a second diameter on the steel bar, where the second diameter is less than the third diameter; wherein

the length and diameter of the steel bar are predetermined based on desired lengths and diameters of the first, second, and third sections after the fourth swaging process is performed.

17. The method of manufacture of claim 16, in which a material of the steel bar is chosen from the group of materials consisting of structural carbon steel not thermally refined, structural carbon steel thermally refined, special alloy steel not thermally refined, and spring steel.

18. The method of manufacture of claim 16, further comprising the step of:

thermally refining the steel bar after the fourth cold drawing process is performed to harden the cold processed steel bar; wherein

a material of the steel bar is chosen from the group of materials consisting of structural steel not thermally refined, structural steel thermally refined, and

special alloy steel.

19. The method of manufacture of claim 16, further comprising the step of:

thermally refining the steel bar before the first cold drawing process is performed to harden the unprocessed steel bar; wherein

a material of the steel bar is structural steel.

20. A method of manufacturing a torsion bar substantially as herein described with reference to the accompanying illustrative drawings.



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